Reflectometry Metrology for EUV Mask Characterization

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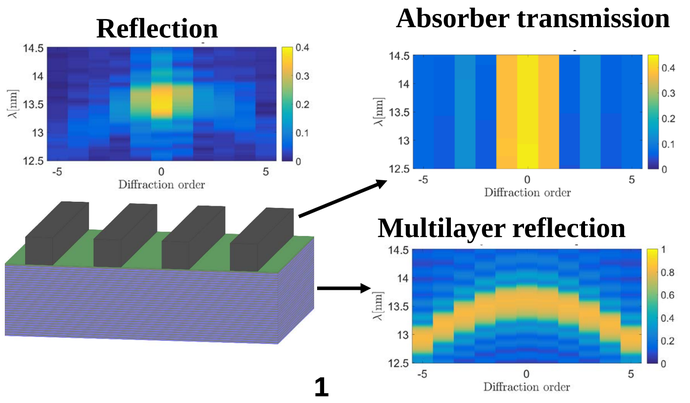
Motivation for actinic EUV reflectometry

- **Reflective geometry** of EUV lithography ⇒ **cross-talk** between **absorber pattern** and **multilayer mirror**



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Objectives

1. Characterize multilayer mirror substrate's **complex reflection coefficient** $r(\lambda, \theta)$
   - Multilayer reflectivity measurement
   - Recover layer thicknesses (Fresnel) *or* recover complex function directly (Neural Net)
   - Algorithms: nonlinear optimization of Fresnel coefficient, or Neural Net

2. Recover periodic **3D absorber profile**
   - Diffracted intensity measurement
   - Parametric absorber representation
   - Algorithm: Dictionary-matching

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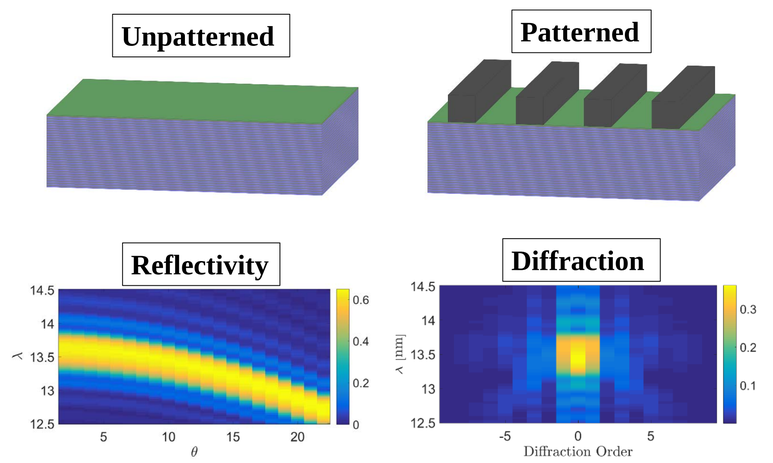
Reflectivity metrology for EUV masks



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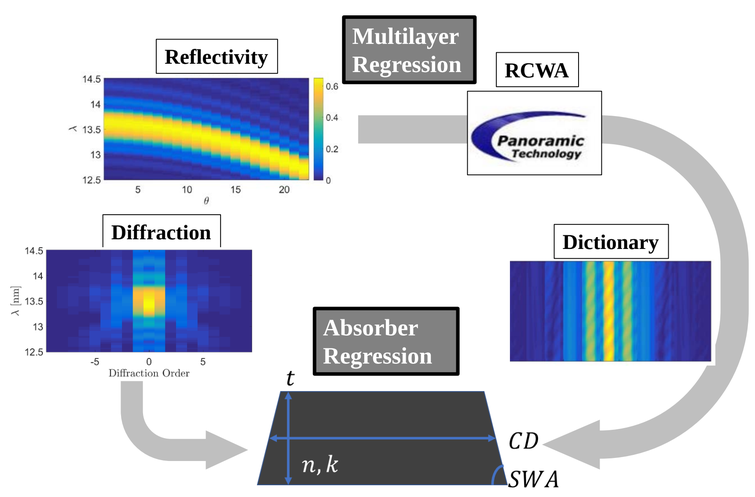
Data Pipeline Overview



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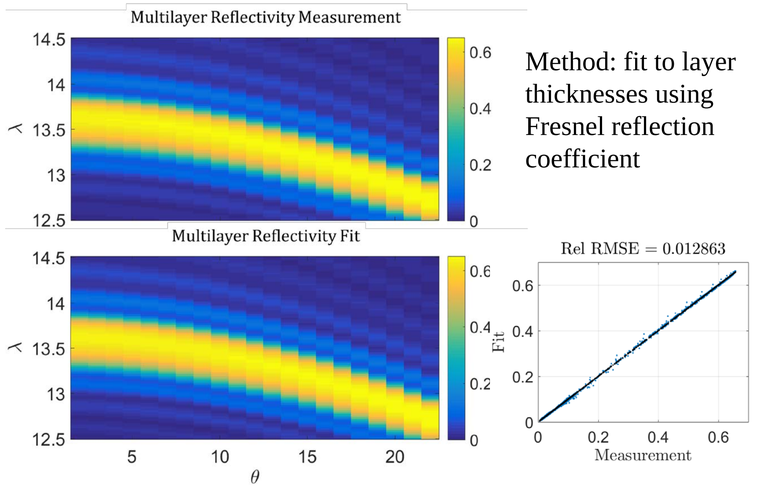
Parametric Fitting of Multilayer Mirror Layer Thicknesses



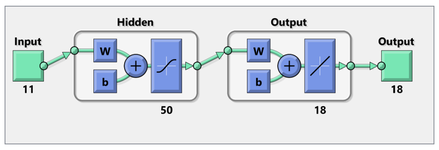
Method: fit to layer thicknesses using Fresnel reflection coefficient

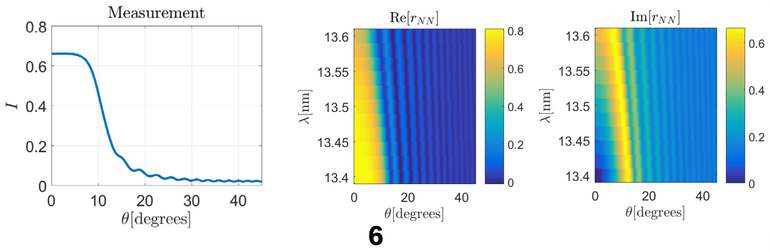
Alternative method: Multilayer phase retrieval with Neural Net

Input: Partially-coherent $R(\theta)$

Very flexible: ideal for custom/aperiodic multilayers

Output: $r(\lambda, \theta)$





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Absorber Profile Regression

- Dictionary of example hyperspectral diffraction signals
  - Best fit = smallest Euclidean distance
  - Interpolation for finer accuracy
- Accuracy—thickness: 0.5nm, Duty cycle: 0.1%
  - $\Delta SWA = 4^o, \sigma_{noise} = 0.4\%$, 7 wavelengths

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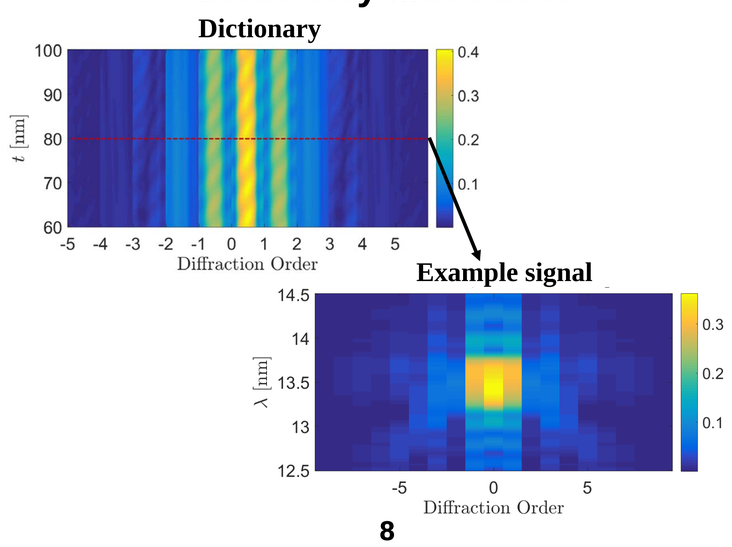
Dictionary Illustration



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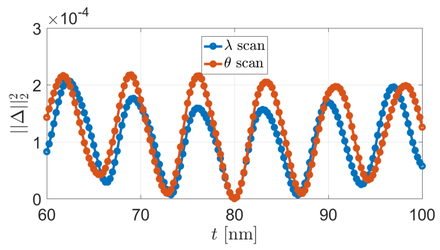
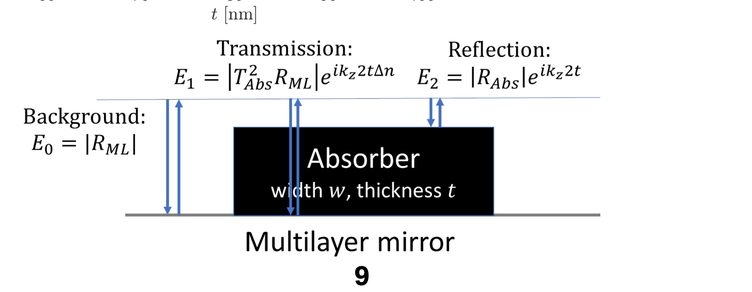
Interference between background and absorber top reflection → ambiguity



Frequency of local minima matches phase difference between E_0, E_2



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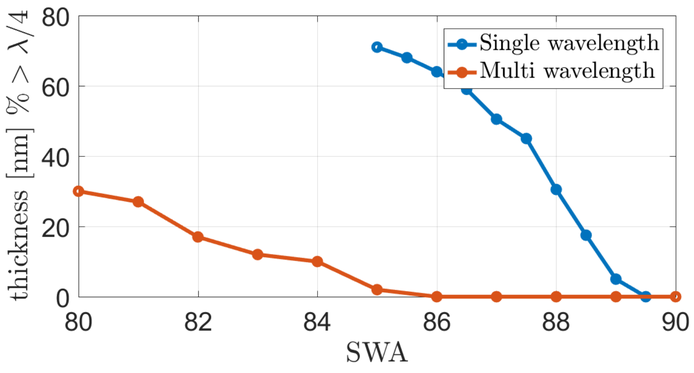
Measuring with multiple wavelengths improves robustness to model mismatch



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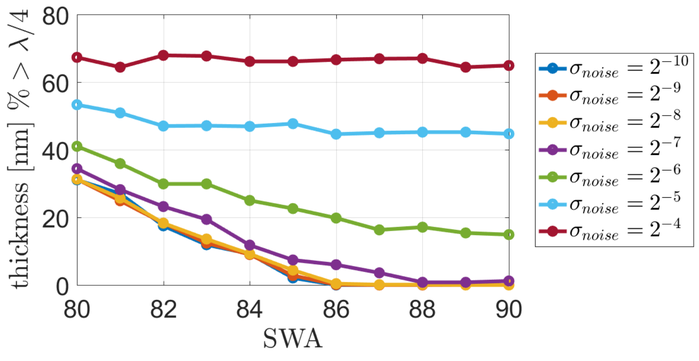
Sensitivity to random + systematic errors



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Future Goals

Enable **precise measurement** of patterned EUV masks

- Explore **sampling vs accuracy** tradeoff
- Analyze physical **design parameters**
  - Target size, spatial/temporal partial coherence, dose
- Include more absorber **profile parameters** in dictionary
- Explore **neural net**/other non-dictionary based approach

Acknowledgment

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